Modeling of Fiber-Reinforced Composite Materials with Interphases

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This paper presents a specialized two-dimensional boundary integral method for modeling fiber-reinforced composite materials with thin bands, or interphases, between the fibers and the surrounding matrix material. The elastic properties of the interphases are different from those of the fibers and the matrix. We idealize the fibers as uniform, infinite circular cylindrical inclusions that are connected to the matrix through coaxial interphases. The bonds between the fibers and the interphases as well as between the interphases and the matrix are assumed to be perfect. In general, the fibers can be distributed randomly (except that they may not overlap), and they can have different elastic properties and sizes. The thicknesses of the interphases and their elastic properties are arbitrary.

The analysis procedure is based on a numerical solution of a complex hypersingular integral equation with the unknown tractions at each circular boundary approximated by a truncated complex Fourier series. A system of linear algebraic equations is obtained by using the classical Galerkin method and the Gauss-Seidel algorithm is used to solve the system. The method allows one to calculate the stress and displacement fields everywhere in the matrix and inside the inclusions and the interphases. Using the assumption of macro-isotropic behavior in a plane section, one can find the effective elastic moduli for an equivalent homogeneous material without the use of simplifying models. The method is capable of solving problems with thousands of fibers on a workstation or desktop computer.

The method can be viewed as an extension of our previous work [1] where simpler spring-like interface conditions were modeled. The present method eliminates physically unrealistic overlapping of the fibers and matrix, which can happen under some loading conditions for the spring-like model. Numerical examples are included to demonstrate the effectiveness of the new approach.

References

1. Mogilevskaya, S.G. and Crouch, S.L. (2002): A Galerkin boundary integral method for multiple circular elastic inclusions with homogeneously imperfect interfaces. *International Journal of Solids and Structures* **39**, 4723-4746.